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ÚSTAV JAZYKŮ

HISTORY OF AUDIO CARRIERS AND TRANSMISSION OF SOUND
HISTORIE ZVUKOVÝCH NOSIČŮ A PŘENOS ZVUKU

BACHELOR'S THESIS
BAKALÁŘSKÁ PRÁCE

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Cílem práce je popsat historii a vývoj zvukových nosičů a jejich vliv na hudební průmysl a kulturu a také nastínit problematiku přenosu zvuku a jeho záznamu.

DOPORUČENÁ LITERATURA:

Morton Jr., David L. Sound Recording: The Life Story of a Technology. The Johns Hopkins University Press, 2006.

Chanan, Michael. Repeated Takes: A Short History of Recording and Its Effects on Music. Verso, 1995.

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Abstract

The purpose of this bachelor thesis is to describe the evolution of audio carriers. This bachelor thesis provides an outlook of history and present of the audio carriers. First of all, this thesis is going to get the reader acquainted with the theory of the sound transmission. It is aimed at propagation of waves and describes their differences. Consequently, analogue and digital means of audio recording are going to be discussed. The main part of this thesis devoted to the preservation of music. Firstly, the non-mechanical preservation of the music is described. This part involves the notation, tablatures, and automatic instruments. The following part deals with the mechanical preservation of the sound and describes the analogue technology of recording devices and audio carriers. In the last chapter, a digital recording and carriers are being discussed. The thesis also informs about the cultural and musical influence of individual audio carriers.

Keywords

sound carriers, music, audio, analogue, digital, signal, waves, notation, phonograph, organ, automatic instruments, mechanical preservation

Abstrakt

Cílem této bakalářské práce je popsat vývoj zvukových nosičů. Tato bakalářská práce poskytuje náhled do historie a současnosti zvukových nosičů. Nejprve seznamuje čtenáře s teorií přenosu zvuku. Tato část je zaměřena na přenos vlnění a popisuje rozdíly mezi vlnami. Následně jsou probírány analogové a digitální způsoby záznamu zvuku. Hlavní část práce se věnuje uchovávání hudby. Nejprve se práce zabývá uchováním hudby před mechanickým záznamem, tato část zahrnuje notaci, tabulatury a automatofony. V další části je již popsán mechanický záznam zvuku, a to v analogové formě. Poslední kapitola je zaměřena na digitální záznam zvuku. V neposlední řadě práce obeznamuje čtenáře s kulturním a hudebním vlivem jednotlivých nosičů. Znalosti jsou nabyty z různých zdrojů, především z literatury.

Klíčová slova

zvukové nosiče, hudba, audio, analogový, digitální, signál, vlnění, notace, fonograf, varhany, automatofony, mechanický záznam

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Prohlášení

Prohlašuji, že semestrální práci na téma *Historie zvukových nosičů a přenos zvuku* jsem vypracovala samostatně pod vedením vedoucí semestrální práce a s použitím odborné literatury a dalších informačních zdrojů, které jsou všechny citovány v práci a uvedeny v seznamu literatury na konci práce.

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V Brně dne ....

Lucie Šimarová

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1. INTRODUCTION

Throughout the history, music developed and was reproduced and kept only by people who handed knowledge of songs to successors. The preservation of music was much more difficult than the preservation of literature for example. Since the 19th century, there were attempts to capture sound. One of the first "successful attempts" were vibrograph and vibraphone. These two devices worked on the same principle. Vibrograph was a simple device consisting of a tuning fork and a cylinder. This cylinder rotated over its vertical axis. The tuning fork made a track of movement; however, this can be considered more as an oscilloscope, due to its capturing and illustration frequency rather than the actual sound. Nevertheless, this was a little step toward the real mechanical capturing of sound that could then be reproduced.

In 1860, Edouard-Leon Scott de Martinville made the very first successful recording of sound. He captured soprano singing "Au Clair de la Lune" on soot-blackened paper. He thought it couldn't work but he patented it. Surprisingly, a few years later, this tune was actually reproduced, and it was found out that his attempt truly succeeded. (Burgess 3)

The true breakthrough came 17 years later, in 1877. Thomas Alva Edison invented the phonograph, which is now considered as the first device that was capable of capturing the sound with the option of its' reproduction. The first ever record was a nursery rhyme "Mary had a little Lamb". (Burgess 5)

Since the 19th century to present time the capturing of sound has gone through many changes. In the main part of this thesis, the capturing of sound developed since the times before mechanical recording to today's technology is going to be discussed. It will also deal with the theory of sound transmission.

2. THEORY OF SOUND TRANSMISSION

2.1. DEFINITION OF SOUND AND THE BEGINNINGS OF ACOUSTICS

In the Cambridge Dictionary, the sound is defined as “something that you can hear or that can be heard.” This is the easiest way to describe the sound, but in this chapter, it would be good to introduce the theory of sound transmission. (sound)

The science that examines sound is called acoustics and is older than one might think. Acoustics has been studied since ancient times, more accurately, this science finds its’ roots 600 years BCE. First studies of sound were made by Pythagoras, who studied music and musical instruments. Pythagoras focused on string instruments and examined the vibration of a string. This is one of the most important studies in history since he described sound as a wave that is being transmitted through some medium. As it is known, this opened doors to the advanced study of sound and led to the general theory of waves. (Morton Jr. 1-2)

2.2. TYPES OF WAVES

2.2.1. MECHANICAL WAVES

Wave propagation is one of the most common physical phenomena. There are different kinds of waves. Even while those differ the basic principles are the same.

Mechanical wave transmits oscillation through some medium. It is necessary to be aware of the fact that wave propagation is connected with the transmission of energy. These waves are always governed by Newton’s laws. Examples are water waves, sound waves, and seismic waves. (Halliday, Resnick, Walker 371)

2.2.2. ELECTROMAGNETIC WAVES

Unlike mechanical waves, these waves do not need any material medium to propagate. They include visible and ultraviolet light, radio and television waves, microwaves, x rays, and radar waves. (Halliday, Resnick, Walker 371)

2.2.3. MATTER WAVES

These waves are less known even though they are commonly used in modern technology. They are associated with atoms, molecules, electrons, protons, and other fundamental particles. (Halliday, Resnick, Walker 371)

2.2.4. TRANSVERSE WAVES

A transverse wave is caused by a simple harmonic motion. An easy example of such wave can be demonstrated on a stretched rope, when one end of the rope is held and moved harmonically upwards and downwards an impulse emerges and travels along the rope in the form of a sinusoid. The motion of an element along transverse wave is perpendicular to the wave's direction. This wave is continuous and has a constant speed. It has either the shape of sine curve or cosine curve. This wave is said to be a travelling wave because it travels from one point to another. Example of a transverse wave is the propagation of light. (Halliday, Resnick, Walker 372)

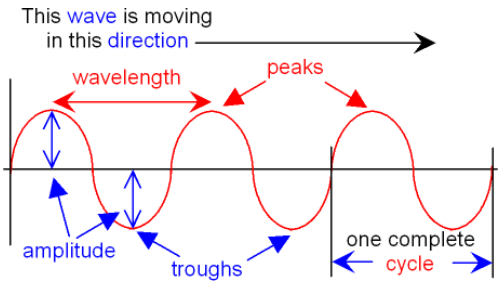


Figure 1:A transverse wave

Figure 2:A transverse wave

2.2.5. LONGITUDINAL WAVES

Longitudinal waves are caused by compression of air. Again, an easy example of these waves can be demonstrated on a pipe in which the air would be pressed and then stretched. If a pipe is terminated with a moveable cover, we can push this cove forward and backward and create a longitudinal wave. It this case the movement of a wave element would be parallel to the direction of the wave's direction, as shown in the figure below. (Halliday, Resnick, Walker 372)

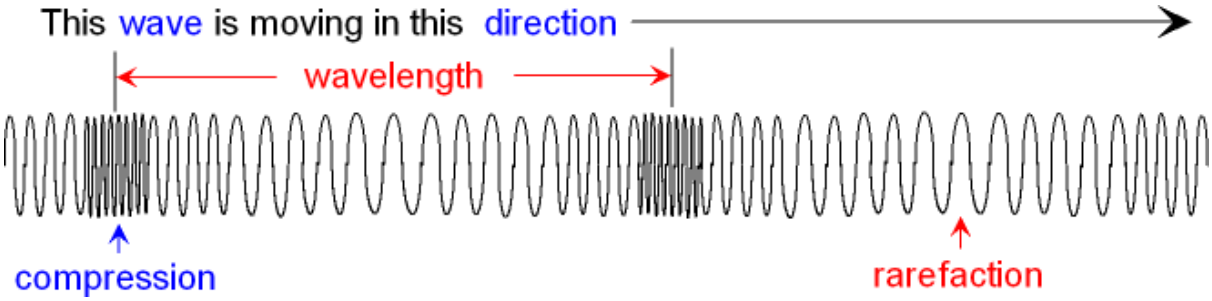


Figure 3: A longitudinal wave

2.3. SOUND WAVES

Sound waves are mechanical longitudinal waves, so they require a material medium to exist. They are described by frequency, length, and speed. We consider the sound as a normal thing of everyday life which mainly brings joy, however, sound can be more important than we might imagine. For example, submarines use sound as a means of orientation, by detection of sound waves they can allocate their position or determine locations of other submarines and objects. (Halliday, Resnick, Walker 399)

2.4. INTENSITY AND SOUND LEVEL

In Fundamentals of Physics, the intensity of sound is defined by words: "The intensity I of a sound wave at a surface is the average rate per unit area at which energy is transferred by the wave through or onto the surface." (Halliday 406)

The intensity of a sound wave depends on the sound source. If the source would transmit sound only in a particular direction the intensity would be different from the one that emerges from a sound that is being transmitted by waves which spread from a source around it. (ibid.)

Humans can hear a wide range of intensities; thus, a term sound level is being introduced to the study of sound. Sound level (β) is given in decibels (dB) by formula $\beta = (10\mathrm{dB})\log\frac{I}{I_0}$, the name of this unit was chosen to recognize the work of Alexander Graham Bell. (Halliday, Resnick, Walker 406-407)

2.5. SOURCES OF MUSICAL SOUND

Musical sounds can be produced by oscillation of strings, membranes, air columns, wooden blocks or steel bars. The examples of waves that were described previously appear again (stretched rope – in this case, it would be a stretched string, pressed air in a pipe – pressed air in trombone). (Halliday, Resnick, Walker 410)

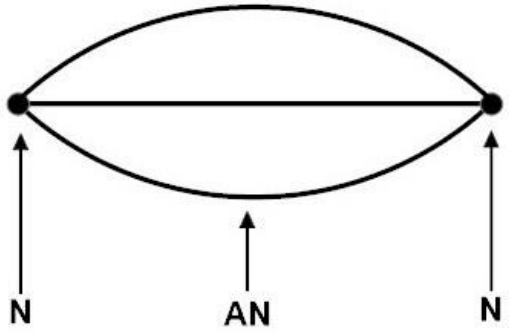


Figure 4: the first harmonic

In figure 3 is shown the first harmonic, also called a fundamental mode. If the pipe has a length of L, the first harmonic requires a wavelength $\lambda = 2L$, the second harmonic is then given by $\lambda = L$, and the third harmonic need a wavelength $\lambda = 2L/3$. (ibid.)

2.6. BEATS

A beat phenomenon is a merging of sounds at similar frequencies. For example, when humans hear a sound of 552Hz and a sound of 564Hz, these two sounds merge together into one sound of 558Hz. This phenomenon is commonly used by musicians for tuning of instruments they use a referential frequency (concert A, 440Hz), the instrument is then tuned until the beat disappears. (Halliday, Resnick, Walker 412)

3. DIVISION OF AUDIO RECORDING ACCORDING TO ANALOGUE AND DIGITAL TECHNIQUES

Audio recording can be divided into two kinds: analogue and digital. It is obvious which one came first, and which appeared lately. The principle of each technique, its advantages and disadvantages, and influence on the evolution of sound recording will be described in this chapter.

3.1. ANALOGUE SIGNAL

Firstly, it is important to define the analogue signal. According to www.dictionary.com analogue signal is “a signal in which some feature increases and decreases in the same way as the thing being transmitted. In AM radio, for example, the strength of the radio wave goes up and down in analogy with the loudness of the original sound.” This definition, in general, is correct, but it would be better to describe analogue signal in more scientific terms. (analog signal)

As it was already established above, in analogue signal some feature increases and some decreases. We can picture the feature as a point travelling on a sine wave. This sine wave has an amplitude, which describes the maximal value, period and frequency; these two are sometimes mismatched. A period is a time for which one cycle holds, frequency, on the other hand, says how many cycles are being repeated.

An analogue signal is thus a continuous sine wave and each position of given point on this wave has a specific value. (Analog vs. Digital)

3.1.1. ANALOGUE AUDIO RECORDING

The analogue recording was the first means of capturing sound and was primarily used until 1970'. The analogue signal was directly recorded to a recording medium using a microphone (or another capturing device). The amplified sound from the carrier than corresponded exactly to the source sound because its analogue form has not changed. This is the main reason why people tend to listen to gramophone discs even in the digital age of music, even though the difference of analogue sound is hard to distinguish from the digital one if we do not count the noise which is an inseparable part of analogue recordings. (Does digital sound better than analog?)

3.2. DIGITAL SIGNAL

On www.dictionary.com digital signal is described as “a signal in which the original information is converted into a string of bits before being transmitted. A radio signal, for example, will be either on or off. Digital signals can be sent for long distances and suffer less interference than analogue signals.” (digital signal)

This description explains also the advantages of the digital signal. On the other hand, it is important to realize that a digital signal is a form of signal, that was developed by people. Unlike an analogue signal, the digital signal cannot be found in nature. Digitalisation is a way of simplifying given signal, so it is easier to be processed.

The digital signal is either represented by square waves, where the values are typically in range 0 to 5V. Or it can be a discrete representation of an analogue signal. (Analog vs. Digital)

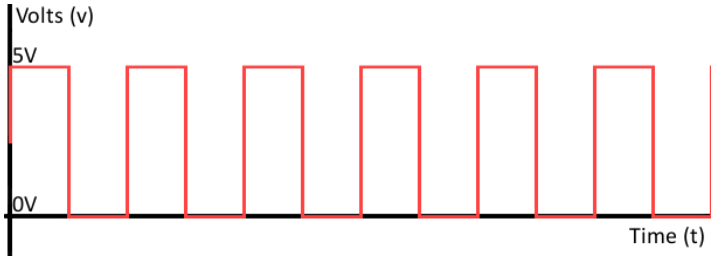


Figure 5: Square wave

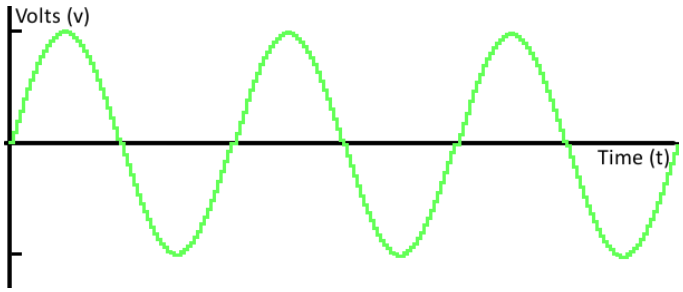


Figure 6: Discrete analogue signal

3.2.1. DIGITAL AUDIO RECORDING

Digital recording of sound preserves audio signal in binary digital form and due to the digitization, it loses the option of exact preservation of source sound, however, that is the only disadvantage of digital recording. On the other hand, it provides high-quality sound stored on compact discs, without noise and unlike gramophone discs and magnetic tapes, compact discs do not suffer from vulnerability and the preservation of sound to this medium is indefinite. Another great advantage of compact discs and digital recording is the possibility of making an infinite number of copies even at home. (Does digital sound better than analog?)

4. BEGINNINGS OF MUSIC PRESERVATION

Before there was a mechanical recording of sound, music was preserved on paper. This system of storing "the music data" worked for hundreds of years and is still used nowadays. People usually connect storing of music data only with the mechanical recording, because they are used the physical perception of sound that is recorded, transmitted and then amplified. But in this subchapter, the notation is going to be discussed. (Slabý 9)

4.1. THE NOTATION

The notation is the oldest method of preserving music. The first finding of notation is said to be over four thousand years old. This notation was supposedly found in Iraq and it seems to be simplified form of newer notation, however, it included diatonic scale ("a musical scale that is either major or minor" (Diatonic scale)) and was written for several musical instruments. (own translation, Slabý 9)

Vojtěch Slabý, in his theses *Vývoj zaznamenávání zvuku a záznamových médií po současnost*, says: "The newer Greek notation was capable of a more precise capture of music. It used the signs that were written above words and indicated length, height and partially also harmony and strength of a sound." (ibid.)

The Neumatic notation probably developed from Greek and Roman literature and finds its roots in early Middle Ages – the 9th century. It was used to preserve the Gregorian chants. This notation consisted of two parts. One part was a line containing the lyrics and the second part was a line above lyrics containing sings. These signs cannot be thought about actual notes and they were given specific name neuma. They did not determine the precise note but were more like an illustration of conductor's hand movement and shown whether the melody is increasing or decreasing. This was indicated by two signs, actus for increasing of melody and gravis for indication of decreasing. Also, they did not determine duration and height of a tone or intervals and rhythm of a composition. (Parrish, McKinnon 4)

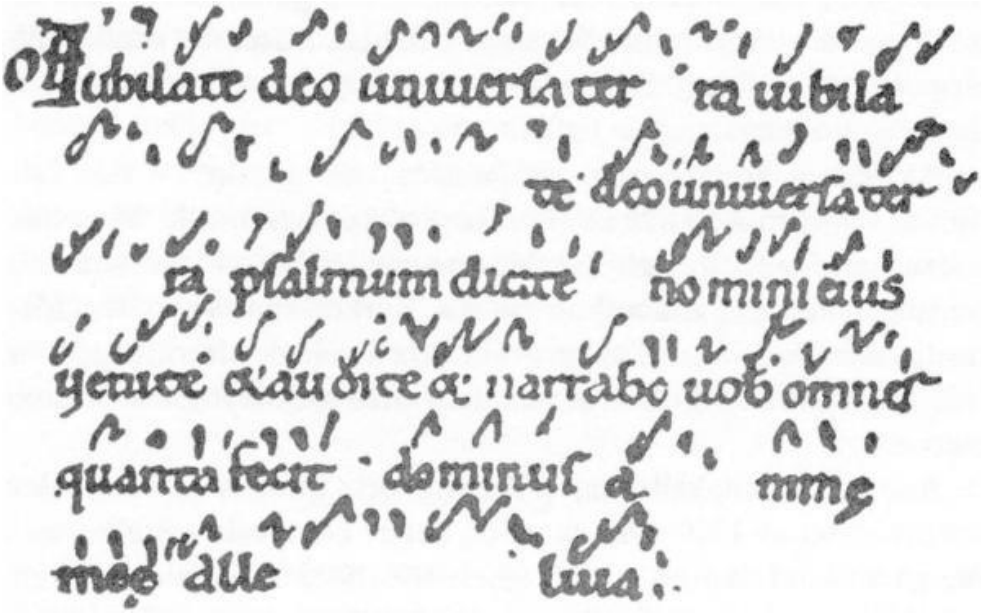


Figure 7: Neumatic notation

The Neumatic notation developed so it could later describe the height of tones. It was done by writing neuma to lines. At first, there was only one horizontal line and later was introduced the second line. These lines were differentiated by colours and they had the meaning of tones. The upper line indicated F and was green, the lower was C and was red. By introduction of these lines to the notation, it was possible to identify the semitones of individual tones. (Parrish, McKinnon 9)

The next progress is attributed to Guido of Arezzo. He was a Benedictine monk, who was also a medieval musical theorist and contributed to notation development by introducing the third line into the Neumatic notation. That was a basis for tertiary spacing and is used to nowadays. Subsequently, Guido extended notation of the fourth line and later sixth line.The Gregorian chants were then preserved in this form. After a while, the colourful notation was upgraded once more. Guido invented clefs for f and c tones. With the use of clefs, there was no need for indicating colour lines. Guido also named the basic tones: Ut, Re, Mi, Fa, So, La, which corresponded to the first syllables of each verse of the Hymn of Saint John "Ut queant laxis" (Mengozzi 1)

During the development of this notation signs as empty squares were also introduced, full squares and dashes. There were added length values and one more clef. The ligature system was developing. Nowadays the dot after a note is commonly used and known as a sign that prolongs the length of tone by a half duration of this tone. This dot was also firstly

used in Mensural notation. This notation spread all over Europe in the 15th and the 16th century and built the basics of today's notation. (own translation, Slabý 10)

Until the 16th century the notes had shapes of squares, but in the 16th century, it was changed to rounded shapes. And in the 17th century, the notation included also vertical lines that separated bars. In Baroque, the notation was modified to current form. (own translation, Slabý 11)

Today's notation consists of five horizontal lines, it also uses clefs, vertical lines, dashes, signs called notes which are oblong and can be prolonged by use of dot, their length is also determined by its' look. There are several types of notes as a whole, half, quarter, eight and sixteenth. These notes are pictured in the following figure.

Symbol	American (British) Note Names	Beats
	Whole note (Semibreve)	4 beats
	Half note (minim)	2 beats
	Quarter note (crotchet)	1 beat
	Eighth note (quaver)	1/2 beat
	Sixteenth note (semiquaver)	1/4 beat

Figure 8: Types of notes

4.2. TABLATURES

Written preservation of music or melody can be done by notation as was described in the previous subchapter, then by several special types of notation that are used in eastern countries and also by tablatures.

Tablatures are a written graphical form of tone illustration. Their history is longer than some musicians might think. Tablatures were used since Renaissance and Baroque. At those times they served to picture the organ or lute music. (Apel 2)

Tablature is an easier way to capture melody and can be read by people, who do not know

how to read notes. Their principle of tone determination is rather logical than difficult as learning notes.

Today tablatures are commonly used for string instrument brass instruments. For each instrument, the tablature looks different. It consists of horizontal lines and their number is determined by a number of instruments' strings. As an example let's describe guitar tablature. Guitar has six strings so the tablature will have six horizontal lines. The first line belongs to e1 string, then the second line is for b string and so on. On these lines are written numbers, those numbers tell the player at which fret should the appropriate string be pressed. In the picture below is a part of tablature for a song Good riddance (Time of your life) by Green Day. It shows that musician should press the third e6 string and strum it two times, then will be played the third b string, empty g string, empty d string and empty g string again. This melody then repeats. (One repeating part is highlighted by a red rectangle.) For those who can play the guitar, it is also easy to realize that the numbers also picture of held chords, in this case, it was G chord .

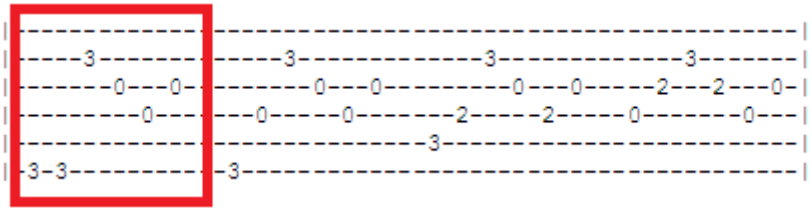


Figure 9: Tablature

It was said that tablatures can be also used for a brass instrument. It this case tablature does not consist of horizontal lines but of vertical dots. The dost have either white or black colour. The black coloured dots indicate that corresponding holes of an instrument are pressed. Otherwise, the system of reading and playing these tablatures is the same as the one for the string instruments.

4.3. CONTEMPORARY TECHNIQUES OF NOTATION AND TABLATURES

With the use of a computer, notes and tablatures can be written more easily and also faster. There are several programs that enable notation and tablature writing, or its reading. Personally, I have used only one of those programs that is called GuitarPro. This program is designated for guitar players and helps them to learn how to play songs. The main advantage of it is that it can actually “play the tablatures”. This means that after inserting a tablature into this program it is possible to press the play button and the program plays the melody of the song and highlights the part that should be played at a certain time. It also has other functions and users can write their own song using notation.

5. A JOURNEY TO THE MECHANICAL CAPTURING OF SOUND

It was already said that preservation of music was enabled by notation and that people are used to a physical perception of sound rather than graphical illustration. Before the mechanical capturing of sound as it is known today, there were some devices, that could carry and play the melody and they belong to the automatic instruments.

5.1. AUTOMATIC INSTRUMENTS

An automatic instrument is a mechanical musical instrument. By using mechanical components this device makes simple music melody. They are predecessors of the phonograph and gramophones.

The first musical instrument of this type was mechanical water organ. It comes from the 9th century. This invention could reproduce music from cylinders and one water organ could play several cylinders because it was possible to change them. inventors of this device were three Iranian religion scholars, they were called Sons of Muse. This organ worked on the principle of a music box. On the surface of the wooden cylinder were many longitudinal wooden sticks. This cylinder rotated around its' axis and the wooden sticks opened and closed outlets to organ pipes in given order. Through those outlets flowed water. After that pipes made the appropriate sound. Cylinders were covered with the sticks, so the proper tones would sound while the cylinder was rotating. It was possible to change the cylinders with different songs. Today this mechanism is quite small, but in the 9th century, it was so big that it could take a huge part of a temple. This mechanism was also used in barrel organ and music wardrobes called orchestrions. This device was firstly made in 1796 by Antoine Favre. Since 1815 orchestrions were mass produced. (own translation, Slabý 12)

5.1.1. BARREL ORGAN

Barrel organ belongs to automatic mechanical instruments and operates on the same principle as the mechanical water organ. This instrument is more known than the water organ and was quickly adopted by large numbers of people. Like a mechanical water organ, this instrument uses rotating cylinders, but they are noticeably smaller and barrel organ can be carried and played anywhere the interpreter wants.

Barrel organs became a synonym for a street entertainment and grinders can be now considered the first buskers. Music is preserved on barrels on which pins or nails are disposed. The organ is played by moving a crank in a clockwise direction causing the inner mechanics of barrel to turn. Pins on the rotating barrel caused opening of valves allowing air into the pipes. Large barrels could contain up to 8 songs. Grinders played the organs in streets since the end of the19th century and this entertainment was a long time the only "public mechanical music" people could hear. Sometimes grinders were considered to be just beggars since many of them were war veterans trying to earn money by playing. (A Short History of Organ Grinders)

Today barrel organ belongs to an expansive instrument because there are not many people left, who can make the melody cylinders. It is also hard to find a functional instrument of this kind and its renovation is also expensive, but they can be found in museums and there are still people who play it. An exhibition of automatophones, which includes also barrel organs, can be found for example at Technical Museum in Brno.

Interesting attempt to revive this old instrument is now developing in the Czech Republic. After organ barrels sank into oblivion, there is only one company in the Czech Republic, which can still produce them. Organ Sevice from Olomouc came up with an idea that barrel organs can be modernized. This company decided to make a newer version of barrel organs. It still looks the same, also the principle of playing remained, but inside the barrel is no longer a set of rotating cylinders, they are replaced with flash drives with uploaded melodies. (own translation, Firma spojila klasiku s elektronikou, vyrábí „flashinety“ 21. století)

“The sound was not damaged by this at all and the barrel organ is thus much lighter. Nowadays, who would bother to carry around some forty kilos heavy case.” (own translation, Ivo Roháč)

5.1.2. PIANOLA

The first pianola was made by Edwin Scott Voltey in the year 1895 and after joining Aelian Company the pianola was commercially introduced. Pianola combines the principle of classic piano and automatic instrument technology. The instrument is controlled by players feet, by stepping on pedals the pressurized air in the instrument is controlled. Music rolls containing particular compositions are placed inside pianola. (History of the Pianola)

Pianola is the closest device to sound carrier, as it is known today. It was an instrument that played automatically, without the help of a person. (own translation, Slabý 13)

The pianola completed by Edwin Scott Votey in the year 1895 at home was later commercially introduced when he joined the Aeolian company, which put the instrument on sale in the USA in autumn 1898. One or two months later after this, pianola was also brought to Europe. (The pianola institute, 2011)

Pianolas are made in two sizes. Same as classical piano, pianola is either standard sized – 65 keys on the keyboard, or full-size which has 88 keys. (own translation, Slabý 13)

6. MECHANICAL CAPTURING OF SOUND

This subchapter is going to present the history of mechanical capturing of sound, since its' beginning in the 19th century to present. Until now the non-mechanical preservation and sound theory were described. This chapter is going to cover the problematic of sound capturing, that enabled mankind to keep thousands of records.

6.1. BEFORE THE PHONOGRAPH

The phonograph that was invented by Thomas Alva Edison. is considered the first music carrier But, there was a quite long way since the phonograph was made.

The first attempts to capture sound appeared at the beginning of 19th century. English polymath and scientist Thomas Young (1773 - 1829) described a vibrograph. This device was used for measuring the frequency of a tuning fork by etching its vibrations into a soot-coated cylinder. (Burgess 3) The figure bellow shows, how the vibrograph looked. There were two weights attached (labels D and E) and they regulated speed. Then the cylinder labelled H fell down the axis as the cord unwounded. (Phonograph history)

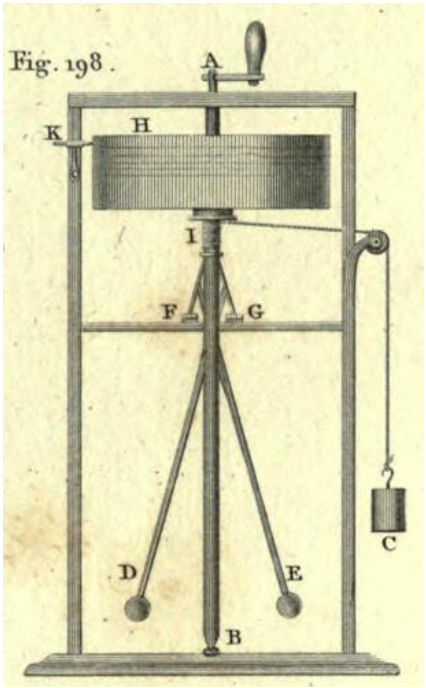
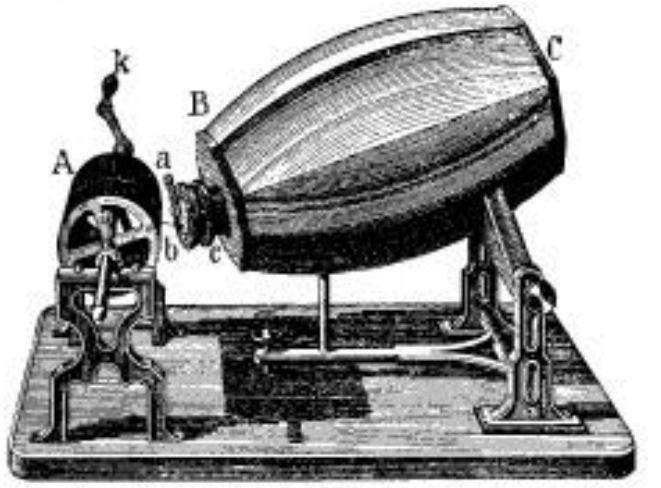


Figure 10: Youngs' vibrograph

The next step towards the invention of the phonograph was made by Édouard-Léon Scott de Martinville, a French printer and bookseller, who was interested in sound. His invention, called phonoautograph was introduced in 1856. “This device used a cone-shaped horn to capture sound and “focus” it on a flexible membrane stretched across the small end. Sounds captured by the horn made the membrane vibrate rapidly. Linked to the membrane through a delicate mechanism was a pointed stylus, to which the vibrations were transmitted; it too vibrated rapidly. Scott mounted a smooth glass cylinder on the mechanism so that the stylus would lightly touch the surface of the cylinder. Before use, the cylinder would be held over a flame to give it a dark coat of sooth. When all was ready, someone could shout or play a musical instrument near the horn; sound vibrations would be transmitted to the stylus, which would begin to vibrate. If the cylinder was turned rapidly during this, the stylus would scribe this line in the soot, rendering a visible record of the sound. This was most likely the first true instance of a sound being recorded.” (Morton 2)



Phonautograph.

BC, barrel with opening at *C*; *c*, brass tube with membeane and style at *b*, and movable piece *a*, by which the position of the nodal points can be regulated; *k*, handle to turn cylinder (*A*) covered with lampblacked paper.

Figure 11: Phonoautograph

6.2. THE PHONOGRAPH

“The Edison sound recorder was prematurely announced in the United States by Edward Johnson, one of Edison’s talented associates, in the November 17, 1877, issue of *Scientific American*. Although at this time a working machine had probably still not been constructed, Johnson’s description closely resembled some of the ideas recorded in Edison’s laboratory notebook of that period.” (Morton 8)

The invention of the phonograph is attributed to Thomas Alva Edison. A birth of this device came up as a result of work on two other inventions, the telegraph, and the telephone. Edison fumbled with the idea of inventing a device that would record phone calls. One could say that his idea was similar to today's answering machine. In 1877, however, he came up with something that was close to that idea. The device did not record the sound of phone calls but could record direct sound, it was the phonograph. This was a turning point in the development of the audio record. Although there was already a sound recording device, Edison's phonograph was able to record and reproduce the sound. This meant the beginning of a new era, both in the field of music and technique. (ibid.) Edison wanted to get a phone call recording first. He tried this with a diaphragm which had an embossing point and was attached to a fast-spinning paraffin paper. Later, he exchanged paper for a metal cylinder covered with tin foil. This device consisted of two parts. One was used for recording of sound, it worked on the principle that the needle poured a soundtrack into the tin foil. The second part of the device served to read this track, or to reproduce it. The picture shows the invention, which was made by Edison’s mechanic Krues in about 30 hours after Edison gave him a sketch of it. To the surprise of Krues and Edison, the device worked, and the first recording of "Mary had a little Lamb” recited by Edison became the first recording of the phonograph. (History of the Cylinder phonograph)
The principle of the phonograph operation lies in the vibration of a needle (or a stylus), this needle follows a groove on a disc which rotates. (Morton 8-9)

6.2.1. THE CULTURAL INFLUENCE OF THE PHONOGRAPH

Ethnography

Edison's phonograph was of great importance not only for the music industry but also for ethnography. According to Edison, every sound is “fugitive”, this idea has led to the use of the phonograph as a medium for the preservation of minority and the Native Americans folklore and culture. (Brady 2-3)

The ethnographers have agreed that non-mechanical preservation (ie, writings, etc.) cannot capture the spirit of traditions. That's why they started using the phonograph. (ibid.)

Music industry

A juke-box is currently mostly connected with the era of 1960’ to 1990’, we can still find these machines in bars or museums. It is, however, not commonly known that their history is as long as the history of the phonograph. Before phonographs were publicly sold, they were introduced to publicity by L.T.Glass and W.S.Arnold. (Louis T. Glass, 1845-1924)

The first juke-box was invented in year 1889 by Louis T. Glass and his business associate William S. Arnold. They introduced this device which could play songs after inserting of a coin. First, juke-box was placed on the street and become very popular among people. It was not called juke-box, instead, it was given a name “a coin-operated phonograph player”. It could play songs, read stories or tell jokes, after inserting a coin people just chose one of the cylinders and could listen. This was not only a great step forward but also a quite gainful business. One phonograph parlour in Missouri collected 100$ in one week. ((A revolution in the music business: the phonograph))

Later phonographs began to be sold publicly. People could buy phonograph and cylinders with recordings that were about two minutes long. (ibid.)

6.3. GRAPHOPHONE

After the success of phonograph, inventors were curious about the development of a more modern device that would be able to record and play longer recordings than just those about two minutes long. There begun a competition in the haunt for improvement. Alexander Graham Bell, Edison’s rival, won the Volta Prize for the invention of the telephone and he found a way to use the money he received by winning this prize. He

employed his cousin Chichester Bell, and a talented mechanist Charles Sumner Tainter, together they started developing a new device in Volta Laboratory. They obtained one of Edison's tinfoil phonographs and substituted soft wax for the tinfoil recording medium. The device did not differ from phonograph much, the metal cylinder was coater with the wax. Another change of phonograph was a replacement of speaking tube, which Edison used. Instead of this tube, they used a large funnel. One disadvantage of this device lied in its weakness of resulting recording, this was "fixed" by using small rubber tubes which carried the sound to the listener's ears. (Morton 16-17)

Later in the year 1881, Alexander Graham Bell and his companions delivered a box to the Smithsonian Institution, this box was containing their latest wax recorder and a wax cylinder with a note indicating that the wax cylinder contained a recording of words "I am a graphophone and my mother was a phonograph." This was supposed to mean a new era of recording, but a wax recorder was not introduced by the Volta team to the society until 1885. This was supposed to mean a new era of recording, but graphophone was not introduced to society until 1885. The reason for this delay was that the Volta team had to do many improvements and that took the time between 1881 to 1885. The device from 1881 was basically just an adjusted phonograph. However, the graphophone from 1885 was a brand-new device which used a longer, wax-coated cardboard cylinder with dimensions of about six inches in length and over an inch in diameter. The graphophone had two parts a separated recorder and reproducer assemblies. Listening tubes were supplied to reproducer, these ran directly to the listener's ears. The graphophone was designed similarly as the phonograph and needed a mechanical force to operate, it was powered by hand cranking. The advantage of this device was that it was easier to operate. The indication of recording part was also simplified, and so, it was easier to move the reproducer to it when it was needed. (ibid.)

The graphophone was presented to the leaders of Edison Speaking Phonograph Company by Gardiner Hubbard, he was supposed to get the financial support, but it took longer time than Volta group was willing to wait, so they decided to form their own company in 1886. They started marketing the graphophone for entertainment. It did not work quite well, but the Volta graphophone was noticed by few reporters, who found it to be a perfect device for court purposes. (Morton 17)

Even thought, Edison did not admit it he was challenged by the invention of the graphophone and started to work on his own improvements. During 1886 and 1887, he, Charles Batchelor, and other companions of his started to work on duplication of the wax cylinder graphophone. Edison was not satisfied with the wax as a recording medium because of its insufficient properties, wax was too soft and tended to dislodge and cling on the stylus. Edison and Batchelor experimented to find a solution for this problem. They succeeded when they discovered a compound of paraffin wax and a natural resin, this medium was more resistant to dislodging and could perform a louder reproduction. (ibid.)

6.3.1. THE INFLUENCE OF THE GRAPHOPHONE

After the attempts to hit the market of entertainment the Volta team succeeded in another field. The graphophone attracted Andrew Devine at first. He was a reporter (or a secretary) in the U.S. Supreme Court. Devine decided to invest in the Volta company and brought in James O. Celephane. Celephane was a court reporter and shared the vision of Devine. The last men, whose attention was attracted by the graphophone was John H. White, who was a reporter for U.S. House of Representatives. All these men were amazed by the device because it could “take notes” with surprising accuracy. After this, the Volta graphophone was used at courts for reporting and note taking. (Morton 16-17)

6.4. THE PERFECTED PHONOGRAPH

In the year 1888 Edison announced his perfected phonograph. This new device had graphophone design and because Edison was an electricity expert he equipped his phonograph with an electric motor as a power supply. The perfected phonograph disposed of a mechanism that allowed rapid starts and stops, another improvement was an added shaving attachment, this supplied the ability of phonograph to serve as a dictating machine. Early after the announcement of the perfected phonograph, Edison’s investors established Edison Phonograph Company. This got Edison back to the competition and with his Company he was able to compete with Volta team in the field of dictation machine production and decided to hit the entertainment market. Edison was the first inventor, who came up with an idea of talking doll. These dolls should have had inserted a little machine working on the phonograph principle inside. For this purpose, a new company called Edison

Toy Phonograph was established, but this business was not as successful as was predicted due to delay in production of dolls for Christmas 1889, and also for their unreliability. After a short period of time and production of 3 000 dolls, Edison decided to quit this business in 1890. (Morton 18-20)

6.5. THE GRAMOPHONE AND GRAMOPHONE DISCS

6.5.1. THE HISTORY OF THE GRAMOPHONE

The invention of the gramophone cannot be considered as an unexpected technical breakthrough, but it became one of the most popular devices to reproduce music. Since its beginnings, it dominated the market for more than 75 years. The golden age of gramophone and gramophone discs is dated to 1950-1970. Currently gramophone discs are experiencing a great return to market, the old original recordings are valued by collectors and music fans, the newly recorded, so-called remastered, recordings are popular among people, who listen to musicians, who no longer produce music, the "last category" of current gramophone disc production are contemporary artists, who decided to record on gramophone discs.

The public entertainment success was the home record player, but the fame of wax cylinder players began to fade around 1890'. Even though Edison considered the idea to produce flat discs instead of cylinder recordings, he remained with the wax cylinder technology. (Morton 31, 32) The gramophone and flat discs were invented by Emile Berliner, a German inventor, who moved to the United States where he worked several years on devices such as a telephone. On the 16th of May 1888, he introduced his invention to Franklin Institute. E. Berliner's device was similar to phonograph and graphophone, but the principle of recording differed. The phonograph and the graphophone recorded the produced sound on the principle of a vibrating diaphragm which left the recording trace on a suitable medium (wax coated cylinders) and via inverse operation, it could be reproduced to play. Edison's principle of recording differed in the way that it indented a record with an up and down line, on the other hand, Bell's principle lied in cutting an up and down line into a medium. Even though these principles of recording differed they both preserved the sound in the medium by varying in the depth of the trace that was written to the surface of the

wax coat. The difference in the recording on the gramophone discs was that the sound was presented by a sinuous line with a constant depth in the medium. (Reddie 635)

6.5.2. GRAMOPHONE DISCS, RECORDING, AND DUPLICATING

Gramophone discs are Emile Berliner's invention, as he started with a study of the phonograph, his search for a perfect substance began. Apart from sinuous recording line with a constant depth, his intention was a new method of duplicating the records. At first, he tried several substances, the most commonly known being a blackened glass. (The Gramophone) Later on, Berliner used a solid zinc disc, coated with a thin layer of a wax which proved to be the most appropriate solution. The principle of recording and duplicating records is going to be described in this subchapter. (Morton 34)

The gramophone, unlike previous devices, was made only for reproducing recordings. It was important to find a better technology for duplicating records than the cylinder recordings used. The principle included several steps. In the first step, a special recording device scraped a record into a wax which coated the zinc disc. After that, the disc was submerged into a chromic acid bath and left there for a certain time. The wax was used to protect the zinc surface against acidic corrosion, and the grooved parts of an uncovered zinc surface were exposed to the reaction of the zinc with the chromic acid. This chemical reaction caused a deeper groove in the zinc disc. The wax coat was then removed, and the first step of duplication was completed. In the second step, this disc was used for producing a negative copy by electroplating a new metal layer, this layer was then removed and added reinforcing metal layers. The negative was used as a stamp to "print duplicates". The third and the last step was duplicating itself. The duplicated records were made by stamping the negative into a hard rubber compound, vulcanite. This compound was firstly softened by a high temperature and then a negative was pressed into it. (Morton 34, 35)

6.5.3. TYPES OF DISCS

6.5.3.1. REPLICATED COARSE GROOVE DISCS (SHELLAC RECORDS)

The name “shellac records” is used because these discs were made of shellac resin at first, currently, they are usually made of a mixture of mineral powders bonded together by binders. Their great disadvantage is a fragility, and they also need to be kept in good dry conditions otherwise the material would not be chemically stable. (Coarse groove discs)

6.5.3.2. INSTANTANEOUS DISCS

The difference of these discs lies in their unnecessity of galvanoplastic (= electroplating) processing and pressing. They can be either made of homogeneous materials such as PVC, aluminium, zinc, or even a gelatine. On the other hand, they might be made out of substances with a coated surface. They were used in radio stations before the rise of magnetic tapes and can be distinguished by their soft surface or handwritten labels. (Coarse groove discs)

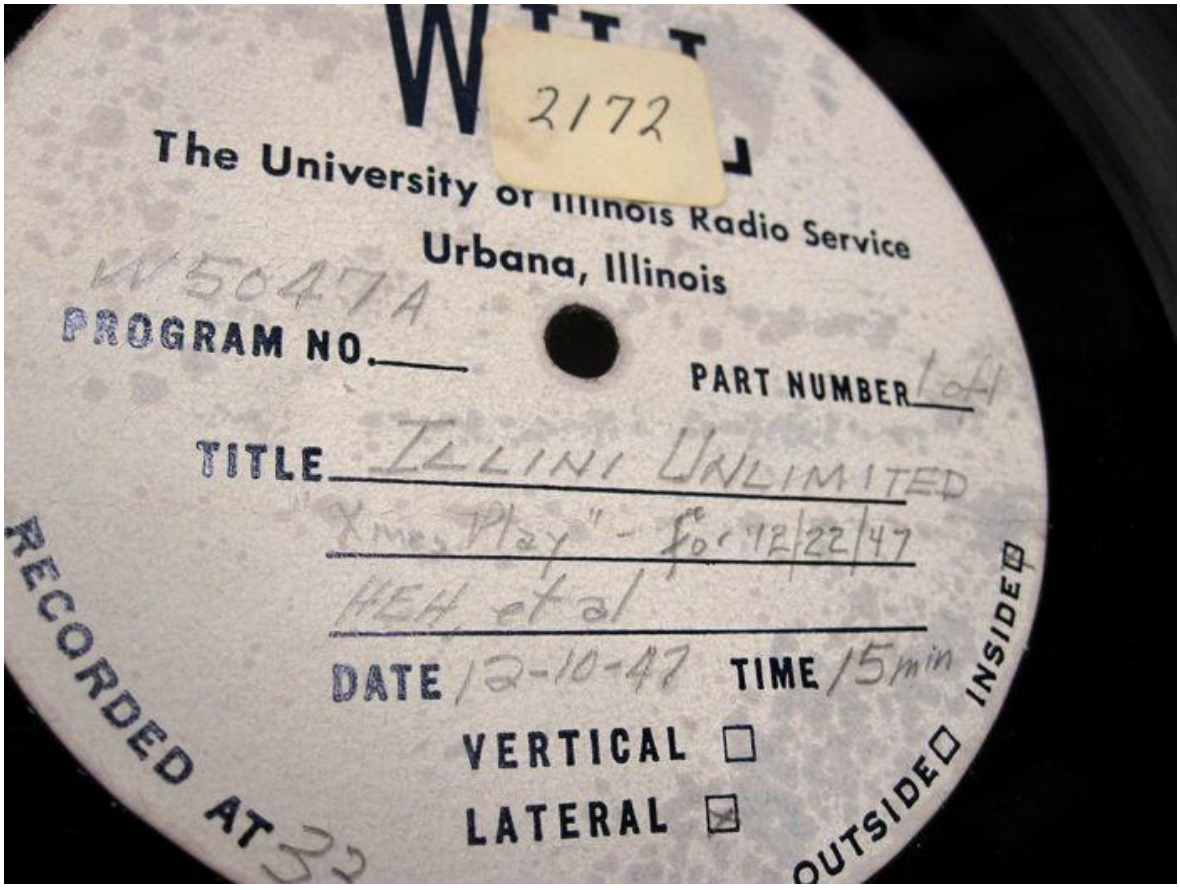


Figure 12: Instantaneous disc

6.5.3.3. LACQUER DISCS

These discs are the most commonly known and also most widespread. The principle of these discs is similar to the basic principle of first discs from Berliner. The substance is a metallic material such as zinc or aluminium which is coated with other substance, in this case, lacquer coating of cellulose nitrate is used instead of vulcanite. The lacquer is usually plasticized with a castor oil or camphor and it carries the sound information. It is easy to identify them because the individual songs are separated by a visible base substance which also forms the centre of the disc. (Coarse groove discs)

Figure 13: Lacquer disc (image courety of Šimarová Lucie)

6.5.4. THE INFLUENCE OF THE GRAMOPHONE AND GRAMOPHONE DISCS

The gramophone discs have had a large impact on the intercourse of cultures. Vinyl records meant a great breakthrough and opened doors for sharing of music and culture. The influence on the recording industry is long-lasting in this case. Vinyl records are the only audio carriers that have been constantly used since their invention to present days.

At this point, the work is going to focus on the impact to American culture. In the year 2012, American singer and songwriter Bob Dylan was awarded the Presidential Medal of Freedom for the life work and the greatest cultural benefit to the country. There might be a speculation that Bob Dylan could have the same cultural influence ever as a writer, but it is undebatable that it was the music which made him famous, his lyrics are the addition which, in this case, exceeded the musical side of his work and became the core. When Dylan was announced to receive the medal, the White House wrote that he had "a considerable influence on the civil rights movement on the 1960' and has had a significant impact on American culture over the pars few decades." The Presidential Medal of Freedom is awarded as a symbol of contribution to the security of national interests of the United States, world peace, or like in Dylan's case as a symbol of cultural and other significant endeavours. The former president, Barack Obama, who awarded Dylan said about him "Not a bigger giant in the history of American music". (Bob Dylan Awarded Presidential Medal of Freedom)

7. MAGNETIC RECORDING

Magnetic recording developed simultaneously with the mechanical gramophone recording. The gramophone discs improved the recording and were able to carry longer recordings, but the technology was still at the beginning and that influenced the quality of the sound. Mechanical recording carried a lot of noise and that was a reason for the search for a more perfect and clean sound. The invention of the phonograph fascinated American engineer Oberlin Smith. Meanwhile, Edison competed with Bell and Berliner, Oberlin started his own research. Even though Smith admired the work of Edison and his phonograph, he was not satisfied with the sound quality and eventually came up with the idea of magnetic recording which could provide better sound quality. Smith invented the magnetic recording but did not patent it and only published his ideas in a technical magazine and that provided his ideas to other investors. (Jankowski 20)

7.1. TELEGRAPHONE

After almost thirty years of inventing that took place in the United States, the development moved to Denmark. Valdemar Poulsen, a Danish electrical engineer, patented and demonstrated the telegraphone. It was the first device for magnetic recording. In the year 1898 Poulsen revealed that it is possible to record sound on a steel wire without creating any groove. For this process, he needed a telephone transmitter that generated a signal in a for on wavering electrical current. The signal represented the sound source, which was obtained from the transmitter (telephone transmitter is a device like a microphone). The signal was transmitted through a wire to an electromagnet. It would magnetize any piece of iron or steal in its vicinity, therefore rapidly passing a long steel wire near it would magnetize the wire along its length and the wire would retain a record of the fluctuations. After a successful attempt of magnetic recording, Poulsen filled a patent application and in the year 1900, he demonstrated his telegraphone at the Paris Exposition. Between the Paris Expo in 1900 and year 1915 Poulsen tried several varieties of the magnetic recording medium. He also invented different types of telegraphone from the phonograph-like one which used a metal cylinder, over a device that used a thin steel tape, to the last one using reels of think wire as a medium. (Morton 50-52)

Poulsen was not the only one, who dealt with the magnetic recording and over the years researchers from United States, Great Britain, and Germany participated on the development of the magnetic recording. (Magnetic recording)

7.1.1. THE MAGNETIC TAPE

The magnetic tape is the most commonly known magnetic carrier due to its wide popularity, even though they are currently disappearing out of their light of fame. The modern tape recording was firstly developed by German inventors for military purposes. After the World War II, the patents for magnetic tape recording were handled by Allies and later shared. (Manquen 903)

The advantages of tape recording over the phonograph and gramophone were a reduction of noise and distortion, a better frequency response and quick restarting of recording after it had been stopped. These advantages are defined by the natural properties of the magnetic tape. (Manquen 904)

The magnetic tape recording is a process in which the sound signal is distributed on a long tape. (Manquen 903-904) The tape is basically a plastic ribbon coated with a magnetizable material that might be for example iron oxide particles. The recording requires a recording apparatus, a recording head, and a recording medium. The sound, in form of electrical signal, passes from apparatus through the head and creates a magnetic print on the tape. When the recorded signal needs to be reproduced back it is only passed through the reproducing head and amplified. This simple process lies in every magnetic tape. (Magnetic recording)

The magnetic tape is installed into the compact cassette. The cassette has two sides A and B which can store a 90-minute footage over a 135 meters long tape. Each cassette consists of two reels and two rollers. The tape revolves from one reel to the other while the recording data is read. In the centres of reels ale cut-outs which serve to spin the rollers, when the tape at side A completely revolved from one reel to the other, the cassette can be switched to the B side and via reverse revolving another side of the tape can be played. (How Tape Recorders Work)

Figure 14: Tape cassette (image courtesy of Šimarová Lucie)

7.1.2. OTHER MAGNETIC CARRIERS

The magnetic tape recording had been introduced but there exist other types of magnetic carriers or storage devices. These manners of preserving data, however, were not designed solely to store sound. Magnetic discs serve to preserve a wide range of data. They are designed similarly as the magnetic tape, except in this case the recording medium is a metal or plastic disc coated with iron oxide. Other mediums might be ferrite cores and drums. They can store any type of data and have been used since 1950' for computers storage devices. (Magnetic recording)

7.1.3. THE INFLUENCE OF THE MAGNETIC TAPE

The cassette technology improved in the late 1970' causing the older technologies to fall in popularity. Its production proved to be quite cheap than other formats while selling for as much or more. But, the technology was supposed to be mainly for recording, not just listening. Unlike other media, it was not popular because of recorded tapes. Its popularity came from being used as a home recording medium, only then it was excepted as a way to

enjoy music. Since it was easy to use the tape technology to make your own recordings the music industry was threatened by the possibility of illegally recorded copies. (Morton 180)

In the early 1980' the Walkman and boombox quickly rose in popularity. And so, cheap and portable recorders made cassettes even more popular. Soon everyone used cassettes whether they were legitimate or counterfeiters. With piracy and counterfeiting having an extreme impact on the whole industry. (Morton 181)

8. DIGITAL AUDIO CARRIERS AND DIGITIZATION OF SOUND

8.1. DIGITIZATION OF SOUND

Digitization of sound implies converting an analogue sound signal to the digital one and it is performed in two steps called sampling and quantization. The sound is recorded using a microphone which captures analogue sinusoidal signal and sends it to the analogue-digital converter where the signal is converted to a binary rate. In the first step of digitization, the signal is sampled in order to obtain a discrete-time signal. This process is expressed by a mathematic formula which evaluates a sine function across the horizontal axis. The sampling theorem, also known as Nyquist-Shannon theorem, states that the sampling frequency must be two times higher than the frequency of a transmitted signal. The second step is quantization and it provides an integral representation of samples in binary form. At this moment, the signal is already in discrete form and the range of integers is called a bit depth. This range determines values of signals that can be recorded. (Digitization)

8.2. COMPACT DISCS

Compact disc, usually labelled by an abbreviation CD, are pure digital carriers. The form of a disc approved to be a sufficient even at the age of gramophone discs, almost hundred years after the invention of the gramophone disc technology, in the year 1982 a compact disc was commercially introduced and become a very popular audio carrier very soon. A moulded plastic material is used for the fabrication of the compact disc to which a sound is recorded in the form of digital data using a laser beam. (Compact discs)

Compact discs have diameter 120 mm and are 1.2 mm thick. The CD consists of clear polycarbonate plastic substrate, a reflective metallic layer, and a clear protective coating of acrylic plastic. The audio data is read in the form of tiny cavities on the reflective metallic layer. These cavities contrast the flat regions that are spread out in a spiral track. (ibid.)

Compact discs use an optical mechanics as the reading device. The CD player consists of a disc drive, a disc drive motor which spins the CD at speeds of 200 or 500 rpm. The next component is a laser lens implanted into a laser pickup assembly which reads the stored digital data using a laser beam. (How CDs Work)

Figure 15: A compact disc

8.3. MAGNETIC TAPES

CDs are not the only carriers that can store digital data. In the previous chapter, an analogue tape recording was discussed but it is necessary to mention that magnetic tapes can be recorded digitally. The digitized signal can be recorded on the magnetic tape using several methods of encoding, the simplest two are a return-to-zero method (RZ) and a non-return-to-zero method (NRZ). The most commonly used is the non-return-to-zero method thanks to its simplicity and great efficiency. This recording is used for mass data storage on hard discs or flash memory cards. Even though the sound is not the primary stored data to the digital magnetic mediums, it is important to realize that compact discs are not the only digital carriers. (Computer Peripherals 1-11)

8.4. THE INFLUENCE OF DIGITIZATION

Since CDs are comparable to gramophone discs, the introduction of CD has never been considered as a great step forward in the music industry. But, CDs have brought many benefits. Unlike previous carriers, CDs are durable, compact, and easy to be mass produced. Their size and use is probably the best impact we can talk about. Even though there were car cassette players, Walkmans and boomboxes before, these technologies improved with the rise of CDs. (Morton 189)

A greater influence might have the digitization itself. By digitization of sound and internet connection of world music can be wide-shared. Currently, it is not necessary to buy records stored on media, many people use pre-payed music applications because they provide "an unlimited music supply".

9. CONCLUSION

The purpose of this bachelor thesis was to briefly introduce the audio carriers and their development in history and specify their cultural and musical impact. It also outlined basics of physics that relate to sound and recording. The aim of this thesis is to give a brief overview of known and lesser-known sound recording methods and audio carriers. This work should provide basic information about mentioned problematics mainly to people interested in music.

At the beginning of this work are described the theory of sound transmission recording techniques. These two chapters should help the reader to understand basic physic concepts and is important as a preface to the following description of the sound recording.

The main part of this thesis concerns the history of music preservation and audio carriers. It familiarizes the reader with the preservation of music since its very beginning and describes the evolution of notation and tablatures. The invention of first audio carriers was a long process, therefore, the predecessors of audio carriers, such as barrel organ and pianola, are also introduced. It is important to be aware of the fact, that the history of non-mechanical music preservation led to technology progress and mechanical recording. The last three chapters deal with the audio carriers themselves, their mastering technologies, and their cultural and musical impact.

The sound recording and audio carriers are, however, a wide topic which cannot be covered perfectly without a great knowledge of physics, electrical engineering, and enthusiasm for music. For these reasons, this thesis should serve only as a brief outlook of this problematics.

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